A vlf up-converter for shortwave receivers

by R. LAPTHORN, BEng, G3XBM*

Introduction

The circuit to be described "up-converts" the fascinating 3-300kHz vlf/lf spectrum to any convenient shortwave range between approximately 3·5 and 25MHz. It has excellent sensitivity and requires no adjustment other than optional crystal netting. Construction is straightforward using a single sided printed circuit board.

Circuit description

From the antenna the received vlf signal is applied to the signal input of a double-balanced mixer, IC1, via a broadband low-pass input filter C8, C9 and L1. This filter, which has a cut-off frequency of approximately 150kHz, attenuates high-level medium and shortwave signals and prevents them from overloading the mixer. Signals above the filter cut-off frequency will be received with reduced strength to beyond 300kHz.

Carrier injection to the mixer is provided by the output of a crystal controlled oscillator, TR1.

The SL1640C has an integral output load resistor with a voltage source output, pin 5, together with a low-impedance emitter-follower output, pin 6, which is used in this converter. The manufacturer recommends that the emitter-follower output should not be used to drive capacitive loads, since signal rectification can occur under such circumstances and result in waveform distortion and harmonic generation. In practice all the prototypes worked without problems when connected to various hf transceivers and shortwave general coverage receivers which presented non-reactive inputs of between 50 and 300Ω. The converter noise figure, typically 10dB, is more then adequate at vlf where external man-made and atmospheric noise can severely limit the usable sensitivity.

Because a double-balanced mixer has inherent rejection of the signal and carrier inputs at the output port, it is possible to receive signals which produce an i.f. that is extremely close to the local oscillator frequency. This is a distinct advantage at vlf where the lowest input frequency may only be a few kilohertz. In practice it should be possible to tune down to approximately 3kHz (100,000m) before the local oscillator overloads most ssb receivers. A receiver possessing a narrow cw crystal filter should maintain good performance to below 1kHz (300,000m).

Using the single sided printed circuit layout provided, construction should present no problems. Holes are provided for two base configurations for TR1, and the metal can SL640C double balanced mixer may be used in place of the SL1640C if the leads are preformed.

The LED, which is not mounted on the pcb, provides an indication that the converter is switched on, and conveniently drops about 1·6V to provide a more appropriate supply voltage for the SL1640C when operating from a 9V battery: a supply of 9V is the absolute maximum recommended by the manufacturer.

The PP3 battery and the printed circuit board used on the prototypes were retained in the RS Components plastic case by means of "Blutak", which is obtainable from most stationers. This is excellent material for retaining lightweight components, thereby avoiding screw holes in the case and pcb.

Results achievable

On completion, no alignment is required unless accurate crystal netting is desired. Both MSF Rugby on 60kHz and BBC Radio 4 on 200kHz should be receivable throughout the British Isles at good strength, so these may be used to adjust C11. For example, if a 14MHz crystal is used, the receiver should be tuned to 14·200kHz and trimmer adjusted until the carrier of Radio 4 produces a zero beat. Time signals from MSF Rugby should then be received on 14·060MHz.

The prototypes were tested on a variety of antennas including a simple 30ft wire around the loft. Even this enabled many vlf stations to be copied, including S9 + 60dB signals from MSF, OMA Czechoslovakia on 50kHz sending time signals, GBR Rugby on 16kHz, and various OMEGA navigational beacons around the world between 10 and 14kHz. Certain natural emissions should be audible below 10kHz with an adequate antenna and an electrically quiet environment.

Many of the signals receivable are facsimile, high speed cw, or rtty transmissions in the fixed and maritime services. Reception of these services is not permitted within the terms of the UK Amateur Sound Licence. However, reception of standard frequency transmissions is permitted and these are plentiful at vlf, where world-wide coverage is possible at all times without ionospheric disturbance.

Conclusions

When used with a selective shortwave receiver and a good antenna this converter provides a first-class vlf receive facility. What we now require is a limited amateur allocation at vlf to enable amateurs to address the challenges of communicating over useful distances with electrically short antennas ($L \ll \lambda$) and consequentially low radiated power. The possibility of such an allocation, regrettably, seems remote.

Acknowledgements

The writer wishes to thank Pye Telecom Ltd for the use of their excellent laboratory facilities while testing the prototypes.

Bibliography

[1] *Linear Integrated Circuit Data Book*—Plessey Semiconductors Ltd.
[2] *VLF Radio Engineering*, A. D. Watt. Pergamon Monograph 1967. This contains a chart showing most vlf transmitters operational at that time and remains relatively accurate.
[3] "Radio Communication at frequencies below 10kHz", R. Lapthorn, BEng, G3XBM—*Radio Communication* April 1975.
[4] *Whistlers and Related Ionospheric Phenomena*, Robert A. Helliwell, Stamford Univ Press 1965.

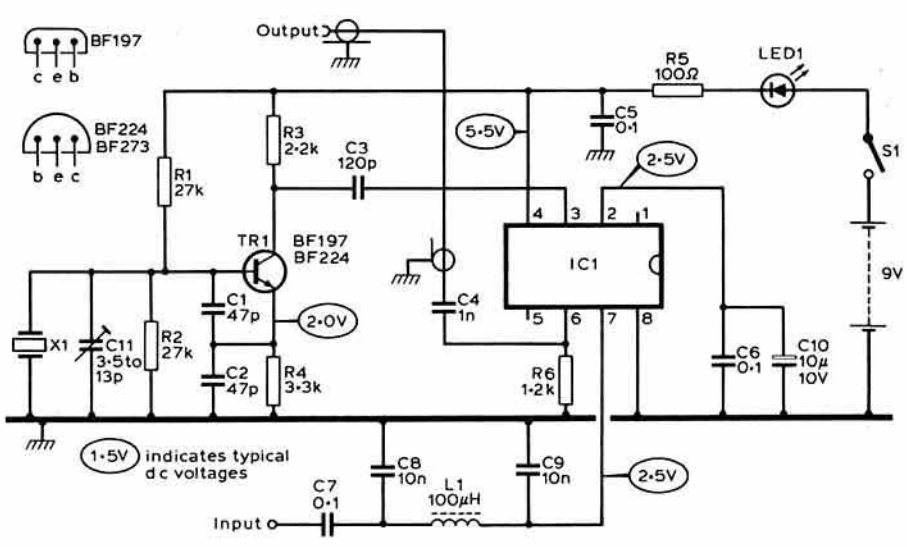

Fig 1. Circuit diagram

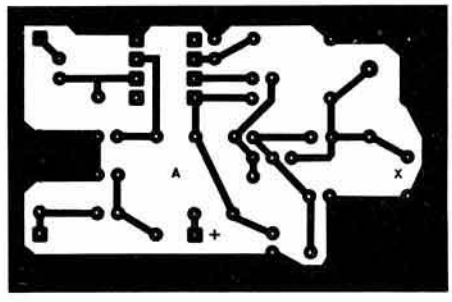

Fig 2. PCB track layout (track side) actual size

*37 Spring Close, Burwell, Cambs CB5 0HF.

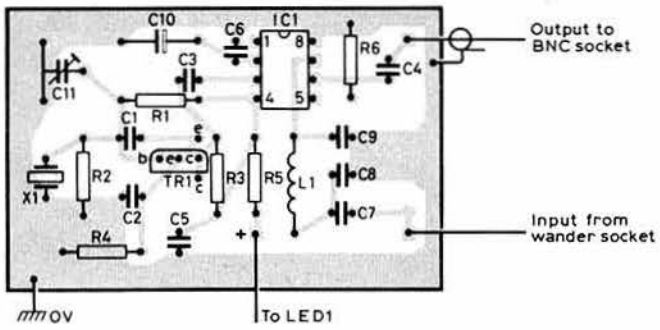

Fig 3. Component layout

Components list

R1,2	27kΩ	C1,2	47pF ceramic
R3	2·2kΩ	C3	120pF ceramic
R4	3·3kΩ	C4	1nF ceramic
R5	100Ω	C5,6,7	0·1μF ceramic
R6	1·2kΩ	C8,9	10nF ceramic
(All 0·25W 10%)		C10	10μF tantalum 10V wkg
L1	100μH choke	C11	3·5-13pf trimmer (for xtal netting if required).

LED 1	Light emitting diode
TR1	BF197, BF273, or similar
IC1	SL1640C or SL640C double-balanced modulators (Plessey)
X1	HC18/U or HC25/U miniature fundamental crystal between 3·5 and 25MHz
9V battery	PP3 or similar
Case	RS Components, stock No 508-914 ABS plastic

□

A simple add-on unit for counting audio frequencies

by I. BRAITHWAITE, G4COL*

THE need occasionally arises in experimental work for an accurate measurement of audio frequency, and where a frequency counter is used there are two common methods of arriving at an accurate answer:

1. Use of a long gate time.

For example, a 10s gate time will allow a frequency of several hundred hertz to be measured to well within 1Hz, while a 1s gate time will produce an uncertainty of one count, ie 1Hz. This method is therefore of little use where input signals disappear or change in frequency within the gate time.

2. Use of the counter in its timer mode.

Here the roles of input signal and counter crystal are reversed. The input signal is used to open and close the gate while the counter's crystal oscillator is counted. This gives an accurate reading of period after as little as one cycle of input frequency. Calculation of reciprocals is required to convert periods to frequencies.

While many amateurs own or have access to a counter, these are often built with rf measurement in mind and have too short a gate time for audio work, and no time mode.

A solution now quite common in instrumentation is to use phase-locked multiplication. The multiplying phase-locked loop is shown in Fig 1. The voltage controlled oscillator (vco) is divided in frequency and compared with the input frequency in the phase detector. The output of the phase detector is filtered and applied to the vco so that it locks to a multiple of the input frequency. The vco can be counted accurately with a short gate time, and this is the principle used in the add-on multiplier.

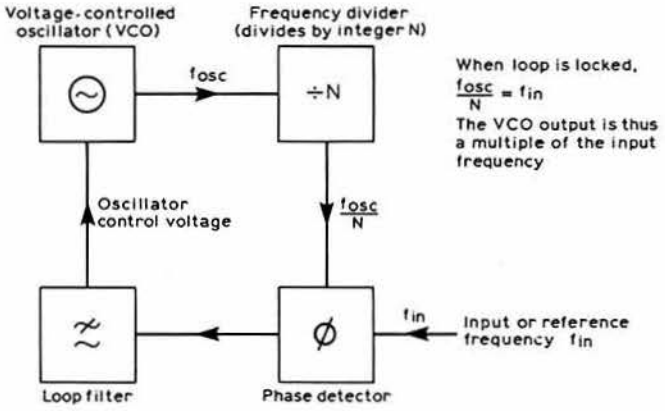

Fig 1. Multiplying phase-locked loop

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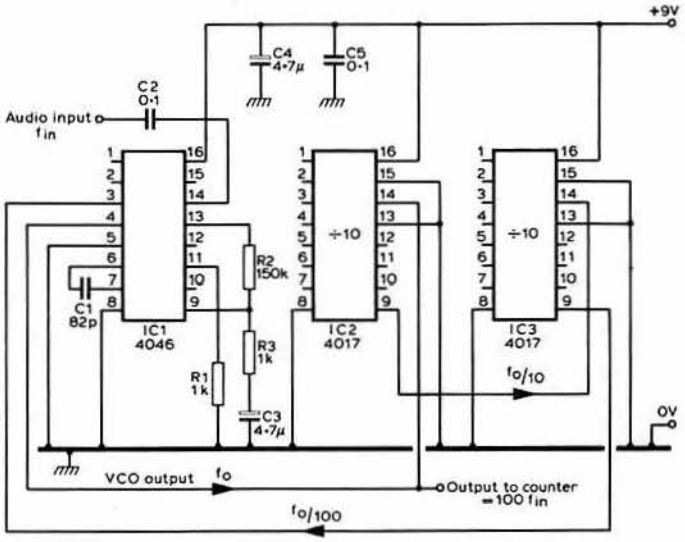

Fig 2. Circuit diagram

Circuit details (Fig 2)

The phase-locked loop contains a division ratio of 100, so the counter receives a signal frequency 100 times that of the input. The vco and phase detector are contained within the cmos 4046 ic. The maximum vco frequency being somewhat above 1MHz, the maximum input frequency is around 10kHz. Above this, many counters can be used directly and accurately.

The loop bandwidth is a compromise between noise rejection and settling time. It is determined by R2, R3 and C3, and experimentation with the values may be worthwhile.

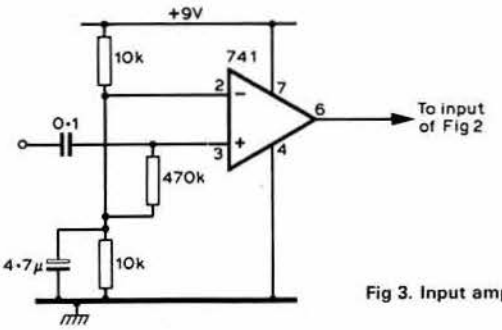

Fig 3. Input amplifier

Construction

The prototype was built as an add-on unit on Veroboard and housed in a plastic box with a screened lead between the multiplier and counter. A PP3 battery is adequate as power supply.

The 4046 will work with input signals in the several hundred millivolt range. If greater sensitivity is required, an input stage as shown in Fig 3 is suggested. □